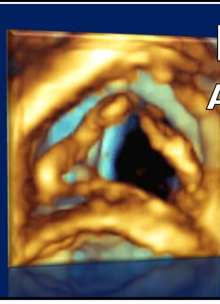
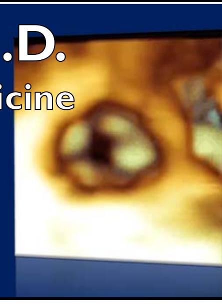
TRICUSPID AND PULMONARY VALVE DISEASE: NEW GUIDELINES

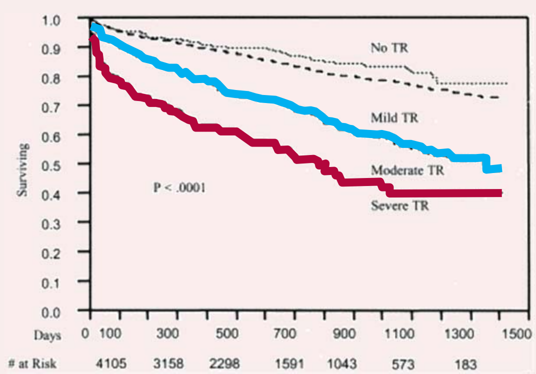


Karima Addetia, M.D.
Assistant Professor of Medicine
University of Chicago

THE UNIVERSITY OF CHICAGO
CARDIAC IMAGING CENTER



IMPACT OF TRICUSPID REGURGITATION



- KM survival curves for patients with TR
- Survival worse in **moderate** and **severe** TR

Nath et. al. J Am Coll Cardiol. 2004;43(3):405-409

CLINICAL PRESENTATION

Highly variable

Symptoms vague → **Asymptomatic, fatigue, RUQ discomfort, fluid retention, peripheral edema**

Physical signs often suggest advanced disease →

Distention of JVP (C-v wave)
Auscultative findings of TR
Findings of PH, RV failure
Hepatic enlargement
Ascites, edema

TRICUSPID VALVE DISEASE

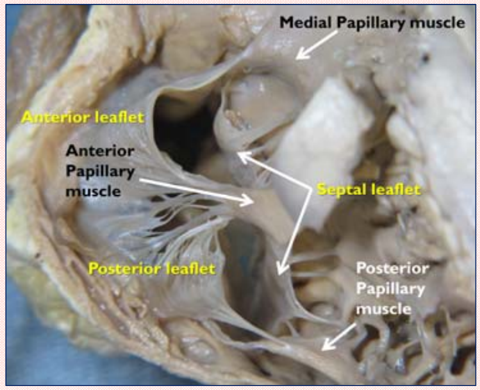
In 2018

…echocardiography remains the mainstay for the assessment of tricuspid regurgitation

Accurate assessment is in YOUR hands

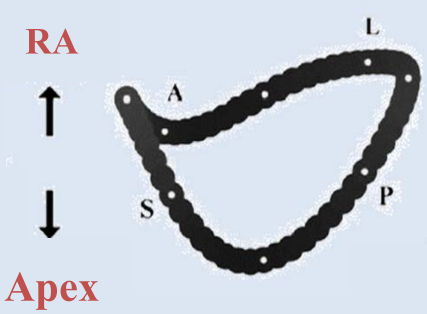
THE NORMAL TRICUSPID VALVE COMPLEX

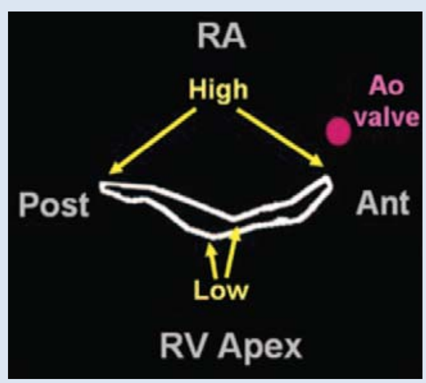
1. Three leaflets
   - Anterior
   - Septal
   - Posterior
2. Fibrous annulus
3. Chordae tendinae
4. Papillary muscles
5. RA myocardium
6. RV myocardium



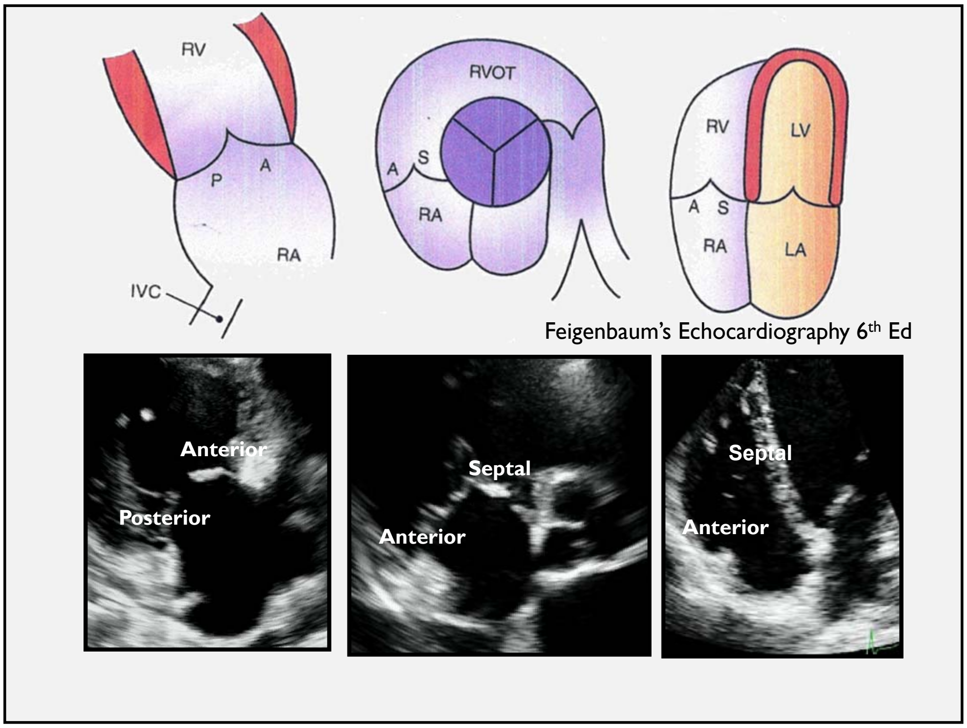
Courtesy Dr. Stephen P. Sanders, Professor of Pediatrics (Cardiology), Harvard Medical School

THE NORMAL TRICUSPID VALVE





Ton-Nu *Circulation. 2006*


RV
P
A
RA
IVC
RVOT
A
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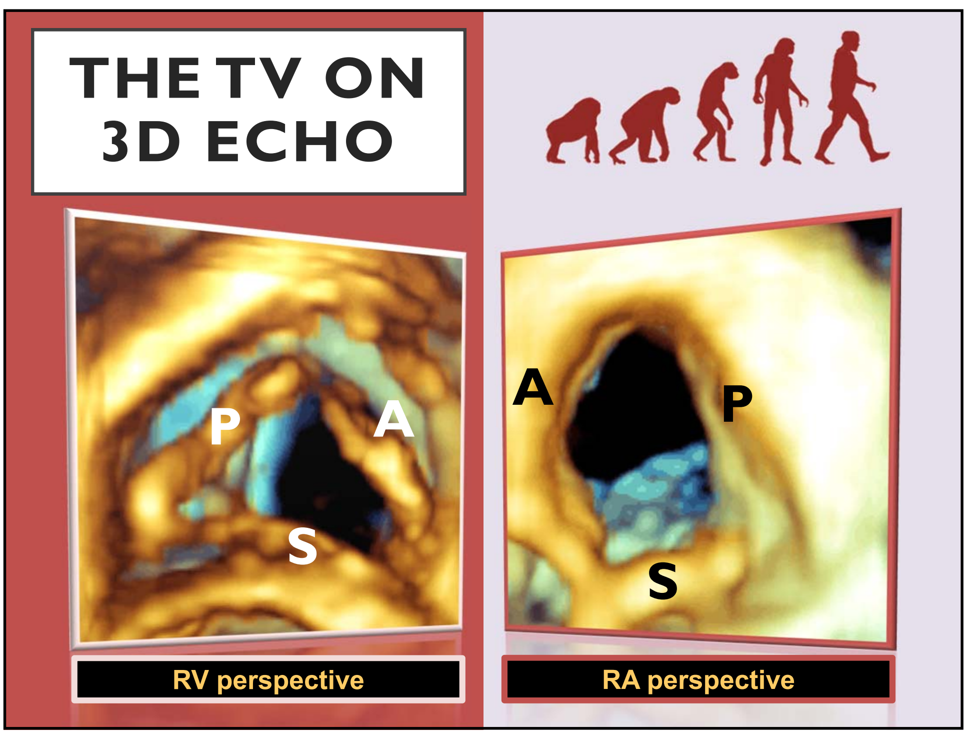
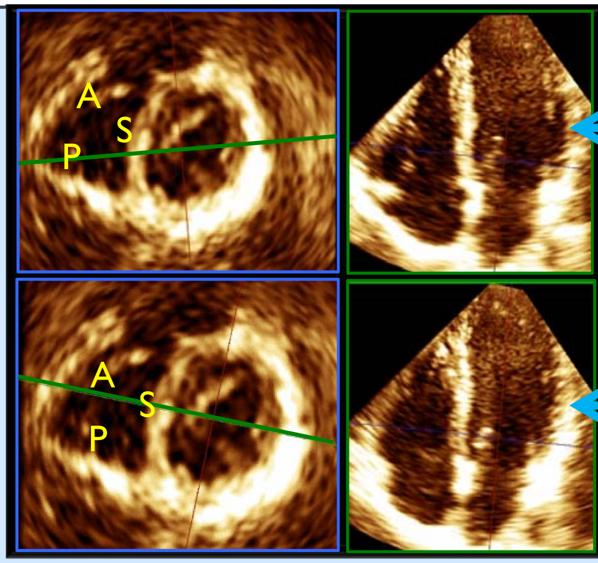
Feigenbaum's Echocardiography 6th Ed
Anterior
Posterior
Septal
Anterior
Septal
Anterior


THE TV ON
3D ECHO
P
A
S
RV perspective
A
P
S
RA perspective

AMBIGUITY OF LEAFLET IMAGED ON 2D



Apical
4-chamber
view

MECHANISMS OF TRICUSPID REGURGITATION

Primary
(or “Organic”)

Intrinsic abnormality of the valve apparatus

15-30%* of TR

Secondary
(or “Functional”)

TV annular dilatation, RV dilatation and papillary muscle displacement

70-85%* of TR

Antunes MJ, Barlow JB, Heart 2007

PRIMARY "ORGANIC" TR

Intrinsic abnormality of TV leaflets and/or support apparatus

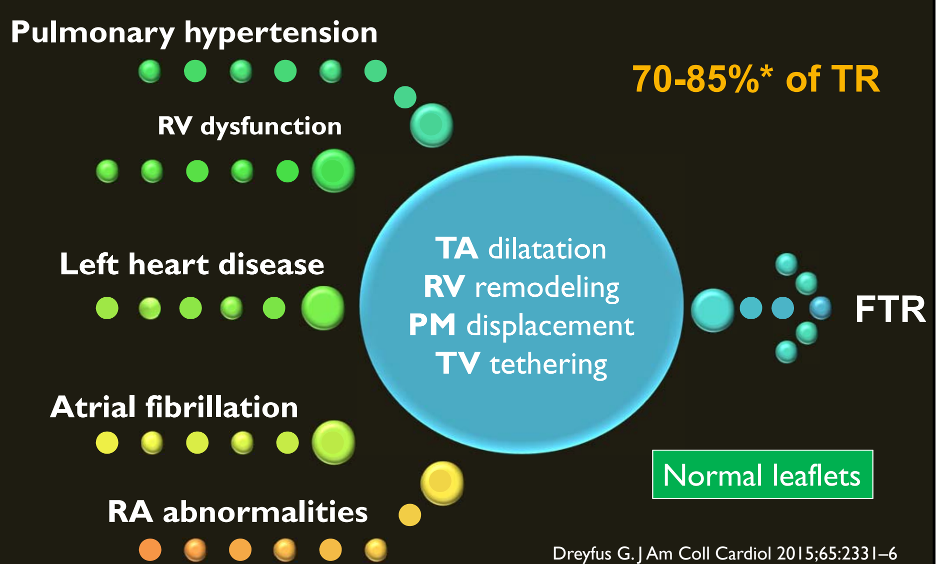
Acquired

- Degenerative, myxomatous
- Rheumatic disease
- Endocarditis
- Carcinoid
- Toxins
- Chest wall trauma
- Iatrogenic (leads, RV biopsy)
- Other (e.g. ischemic, PM rupture)

Congenital

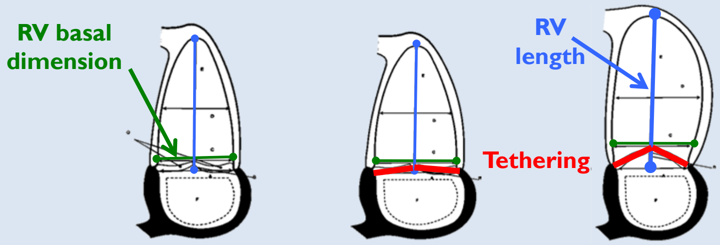
- Ebsteins anomaly
- TV dysplasia
- TV tethering
  - Perimembranous VSD
  - Ventricular septal aneurysm
- Repaired tetralogy of Fallot
- Congenitally corrected TGA
- Other (giant RA)

FUNCTIONAL TRICUSPID REGURGITATION



Dreyfus G. J Am Coll Cardiol 2015;65:2331–6

MECHANISMS OF TRICUSPID REGURGITATION



Group (N)	Controls (99)	Id FTR (141)	PHTN FTR (140)
TR	None	Matched for ERO	
sPAP	Normal	<50 mmHg	≥ 50 mm Hg
Associations:	Controls	Aging, Afib	
TA	Normal	↑↑↑	↑
Tenting	Normal	Normal	↑↑↑
RV Base	Normal	↑↑↑	↑
RV Length	Normal	Normal	↑↑↑
Remodeling	--	Conical	Elliptical

Topilsky Y, Circ Cardiovasc Imaging. 2012;5:314-323

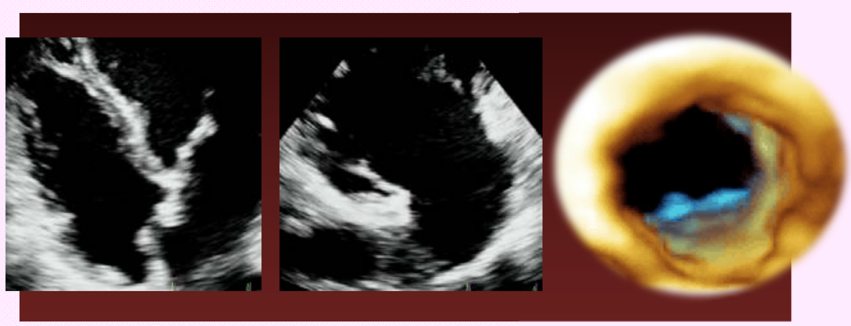
ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

1. Leaflets
   - *Prolapse, flail*
   - *Thickening, restricted*
   - *Coaptation, tethering*
2. Annulus diameter
3. RA size
4. RV size and function
5. Tricuspid valve dysfunction
   - *Stenosis*
   - *Regurgitation: Jet area, VC, PISA, Jet density, Hepatic veins*
6. Systolic PA pressure + IVC
7. Any associated left-sided heart disease

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

1. Leaflets
   - *Prolapse, flail*
   - *Thickening, restricted*
   - *Adequate coaptation?*
   - *Tethering/tenting*
   - *Perforation/ Trauma*

LEAFLETS: PRIMARY "ORGANIC" TR



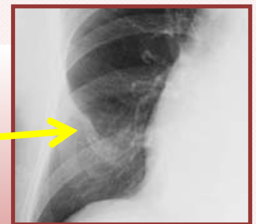
RA perspective

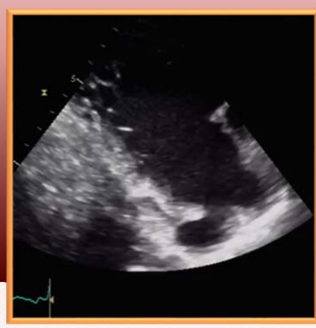
Prolapse – all 3 leafets

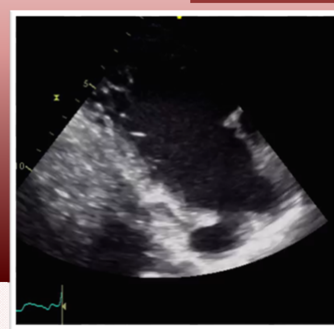
LEAFLETS: PRIMARY "ORGANIC" TR

Traumatic Ruptured TV Leaflet

History of trauma - healed rib fracture

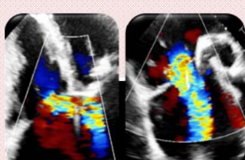


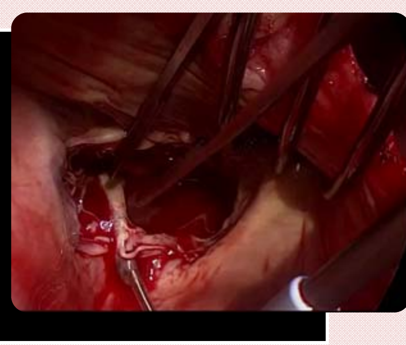


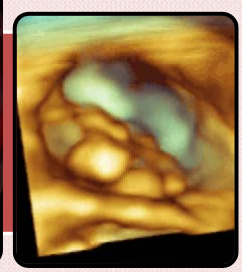


LEAFLETS: PRIMARY "ORGANIC" TR

Iatrogenic: due to lead impingement



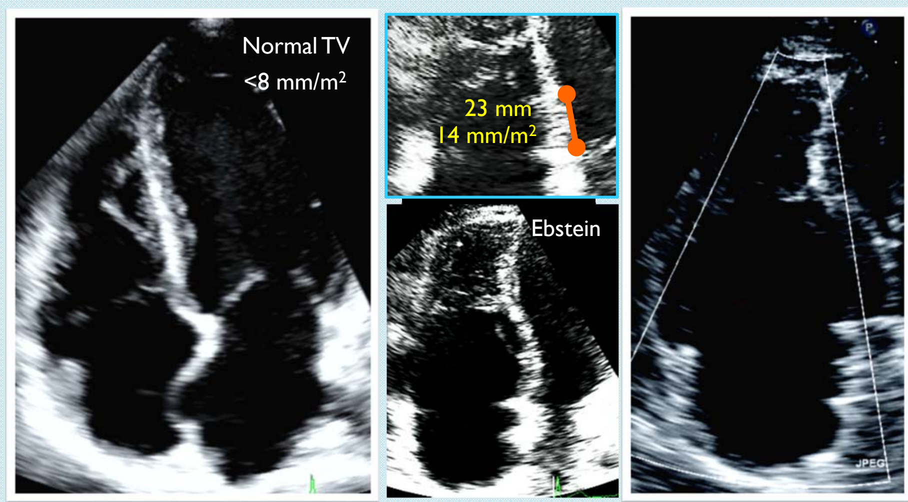




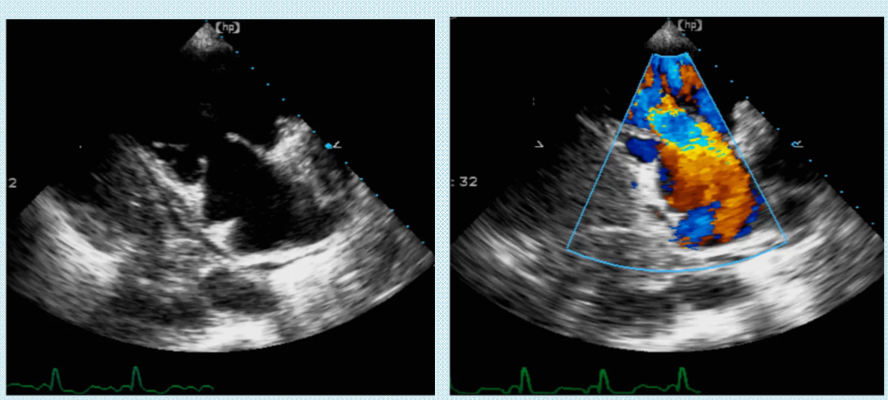
Pre-op **Post-op**

Addetia K et. al. J Am Soc Echocardiogr 2014;27(11):1164-75

LEAFLETS: PRIMARY "ORGANIC" TR



LEAFLETS: PRIMARY "ORGANIC" TR

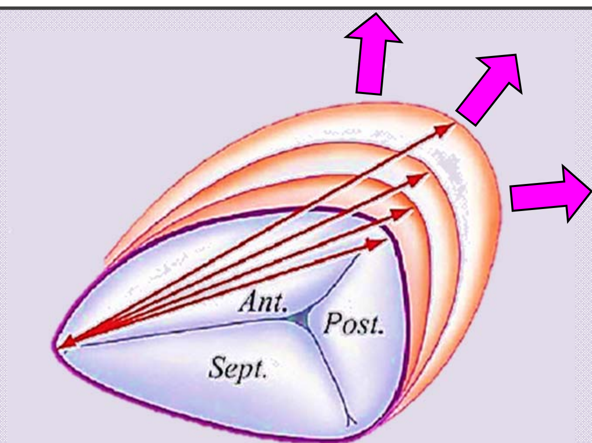


Carcinoid heart disease

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

Annulus diameter

FUNCTIONAL TRICUSPID REGURGITATION

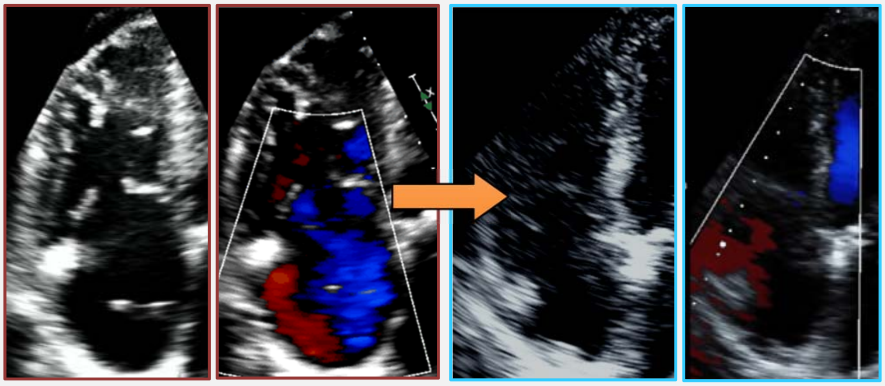


Dreyfus et al. ATS 2005

- TA dilatation occurs mostly along the RV free-wall
- Septal portion of the tricuspid annulus relatively fixed

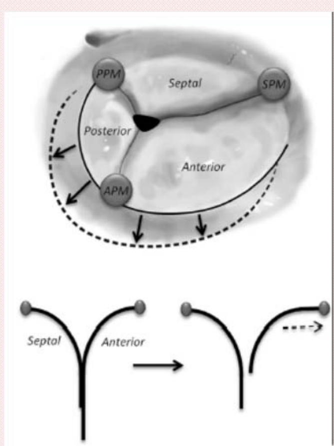
TRICUSPID REGURGITATION IS LOAD DEPENDENT

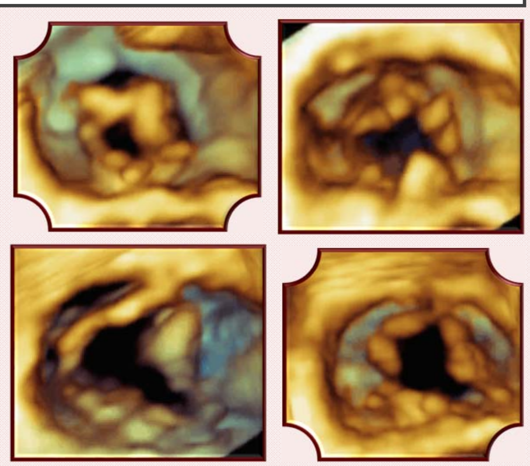
Pre/Post Peritoneal Dialysis: Normal Annular Dimension



Annulus diameter may be a better indicator of TV dysfunction than presence/absence of TR

MECHANISMS OF TRICUSPID REGURGITATION





TR s highly dependent on annular dilatation, with significant TR occurring with only 40% dilatation, whereas it was seen at 75% dilatation in vitro MV studies. i.e. the TV leaks earlier that the MV

Spinner EM. Circulation 2011

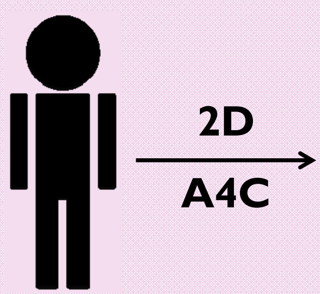
IMPORTANCE OF TRICUSPID ANNULUS SIZE IN SECONDARY TR

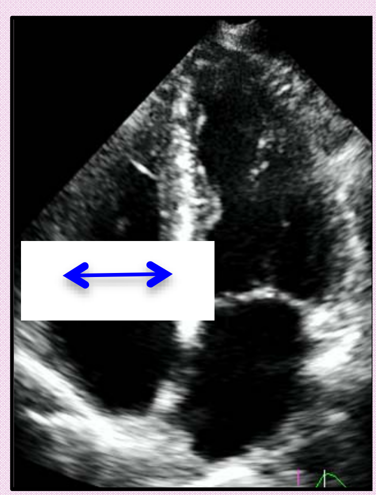
- **N = 311** who had MV repair
- TV annuloplasty performed if TA diameter ≥ 70 mm
- Performing tricuspid annuloplasty based on TA dilatation rather than TR degree results in improved surgical outcome

	MV + TV repair	MV repair only	
Event-free survival @ 10 y	**90.5%**	**93%**	p=NS
Grade III-IV TR	**<1%**	**34%**	p<0.001
Class III-IV CHF	**0%**	**14%**	P < 0.01

Dreyfus et al. Ann Thorac Surg, 2005

FUNCTIONAL TRICUSPID REGURGITATION

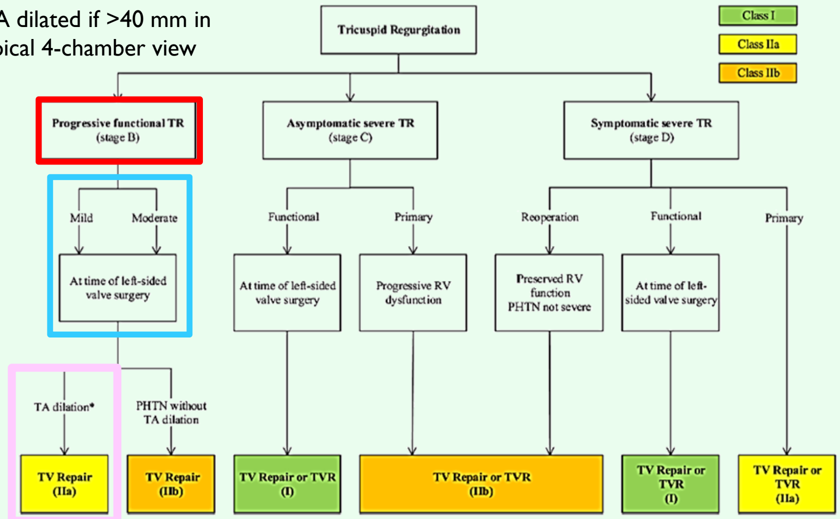




A diastolic diameter >40 mm (or >21mm/m^2) indicates significant annular dilation

THE ACC/AHA 2014 VALVULAR HEART DISEASE GUIDELINES

TA dilated if >40 mm in apical 4-chamber view

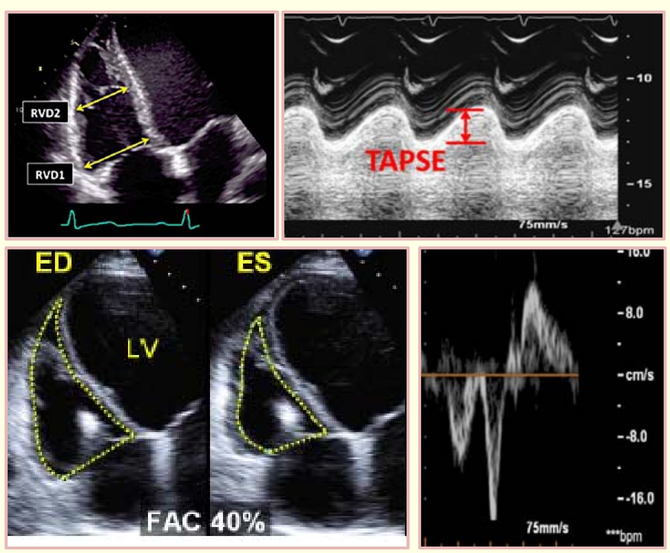


ESC/EACTS Guidelines for management of VHD EHJ 2012

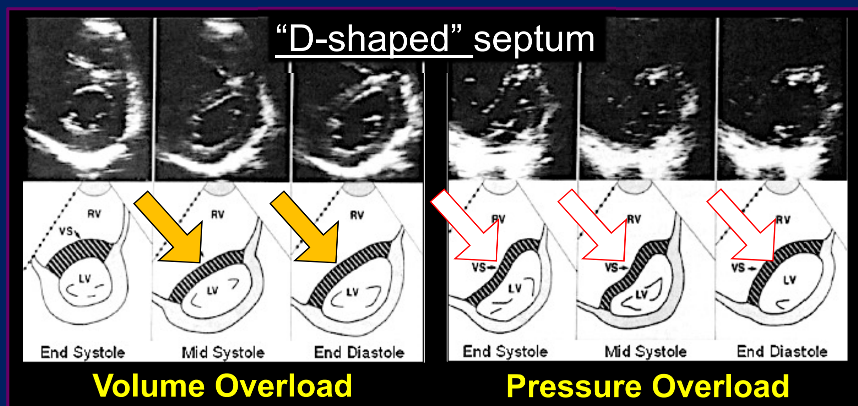
ACC/AHA Guidelines for management of VHD JACC 2014

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

RA size
RV size
and
function



VOLUME OVERLOAD AND PRESSURE OVERLOAD



Ryan T. et. al. J Am Coll Cardiol1985;5:918-24

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

1. Tricuspid valve dysfunction
   - *Regurgitation: Jet area, VC, PISA, Jet density, Hepatic veins*
   - *Stenosis*
2. Systolic PA pressure + IVC
3. Associated left-sided heart disease

ASE GUIDELINES AND STANDARDS

Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation

A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance

William A. Zoghbi, MD, FASE (Chair), David Adams, RCS, RDCS, FASE, Robert O. Bonow, MD, Maurice Enriquez-Sarano, MD, Elyse Foster, MD, FASE, Paul A. Grayburn, MD, FASE, Rebecca T. Hahn, MD, FASE, Yuchi Han, MD, MMSc,* Judy Hung, MD, FASE, Roberto M. Lang, MD, FASE, Stephen H. Little, MD, FASE, Dipan J. Shah, MD, MMSc,* Stanton Shernan, MD, FASE, Paaladinesh Thavendiranathan, MD, MSc, FASE,* James D. Thomas, MD, FASE, and Neil J. Weissman, MD, FASE, *Houston and Dallas, Texas; Durham, North Carolina; Chicago, Illinois; Rochester, Minnesota; San Francisco, California; New York, New York; Philadelphia, Pennsylvania; Boston, Massachusetts; Toronto, Ontario, Canada; and Washington, DC*

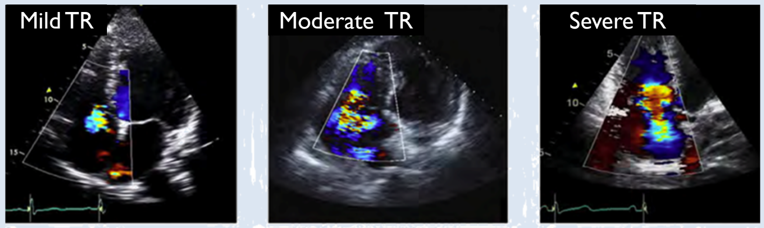
JASE 2017

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

Color Doppler Imaging

1. Jet area
2. Vena contracta
3. Proximal flow convergence

TR QUANTIFICATION: JET AREA



Color flow jet area (cm^2)	Small, narrow	Central, moderate	Large jet, wall impinging, >10 cm^2

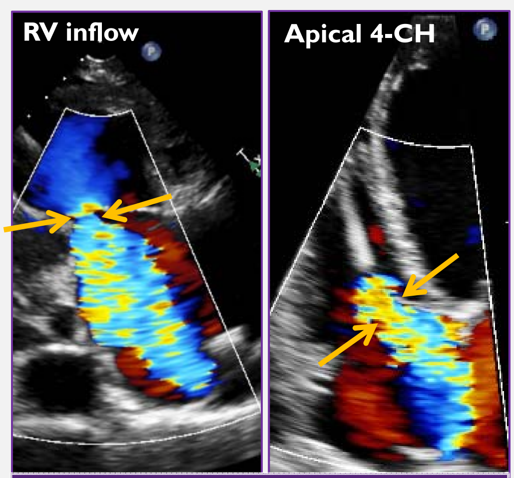
Pitfalls:
- Dependent on driving pressure, jet direction
- May over-estimate central jets and underestimate eccentric jets

Zoghbi W. et. al. JASE 2017

TR QUANTIFICATION: VENA CONTRACTA

Pro
- Independent of flow rate and driving pressure for a fixed orifice
- Less dependent on technical factors
- Good for severe TR

Con
- Problematic in multiple jets
- Convergence zone needs to be seen

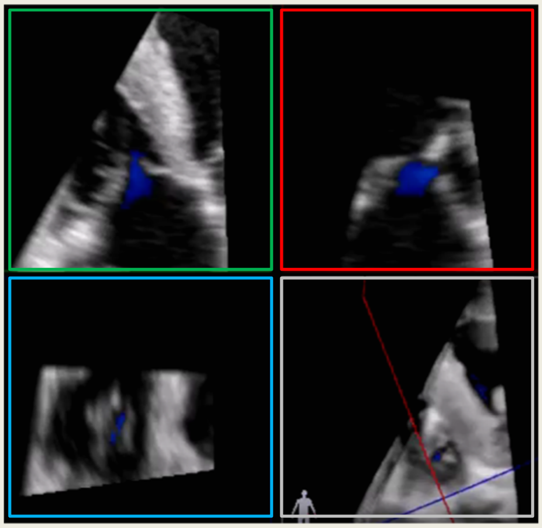


< 0.3 cm = mild; ≥0.7 cm = severe

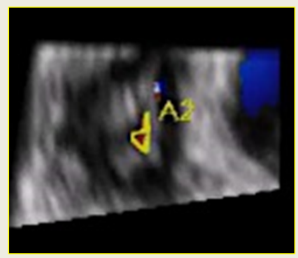
Nyquist 50-60 cm/s

Zoghbi W. et. al. JASE 2017

TR QUANTIFICATION: 3D VENA CONTRACTA AREA

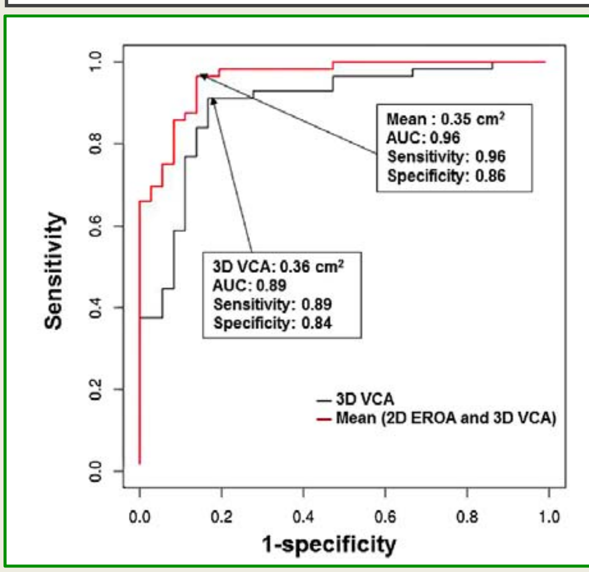


- 3D CD dataset
- Align orthogonal planes along jet
- Use mid-systole
- Limited spatial resolution may lead to overestimation



Zoghbi W. et al. JASE 2017

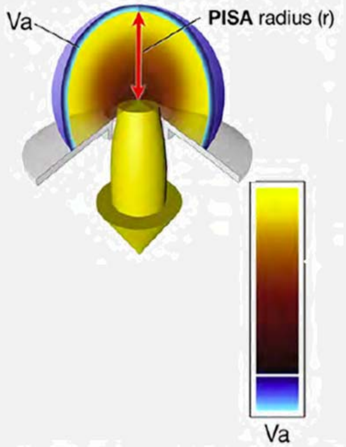
TR QUANTIFICATION: 3D VENA CONTRACTA AREA

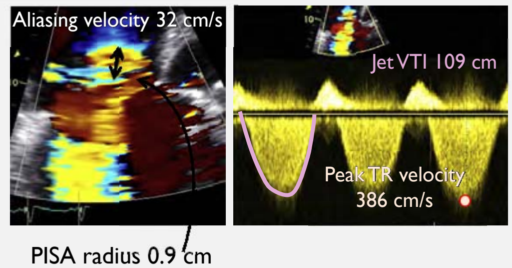


VCA **> 0.4** cm^2 is a reasonable cutoff value for severe TR based on currently available data

Chen TE et. al. et al. JASE 2013
Zoghbi W. et. al. JASE 2017

TR QUANTIFICATION: PROXIMAL ISOVELOCITY FLOW CONVERGENCE





EROA =

$(2 \times 3.14 \times 0.9^2 \times 32) \div 386 = 0.4$ cm^2

RVol = $0.4 \times 109 = 44$ mL

Reg Flow = $2\pi r^2 \times Va$
EROA = Reg Flow/PKV_{Reg}
R Vol = EROA x VTI_{Reg}

Zoghbi W. et. al. JASE 2017

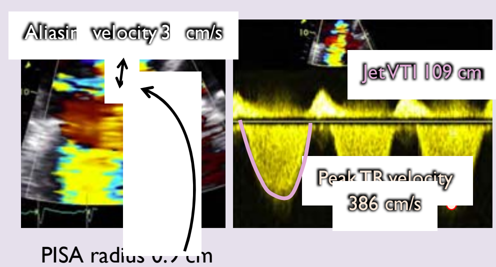
TR QUANTIFICATION: PROXIMAL ISOVELOCITY FLOW CONVERGENCE

Pro

- Rapid assessment
- Quantitative

Con

- Not commonly used
- Multiple jets are problematic
- Non-hemispheric shape can lead to underestimation
- Less experience with TR than MR
- Validated in only a few studies



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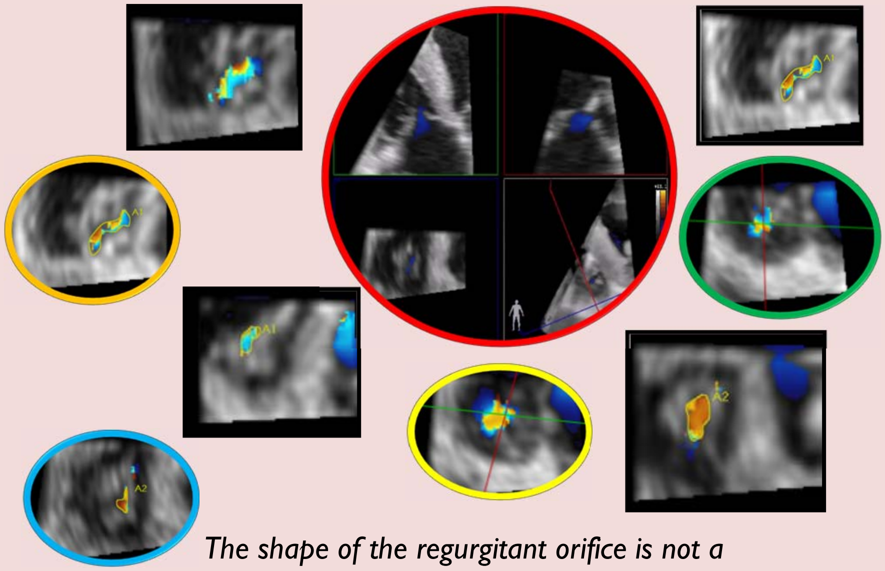
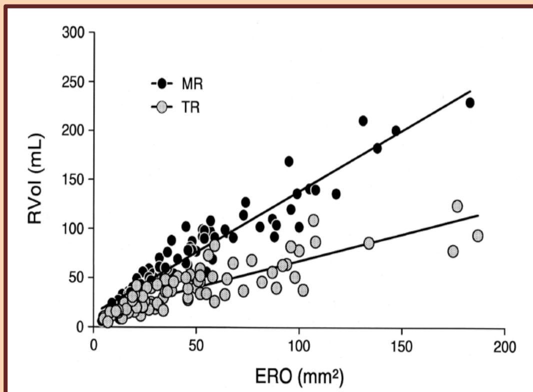
Zoghbi W. et. al. JASE 2017

TR QUANTIFICATION: PROXIMAL ISOVELOCITY FLOW CONVERGENCE



The shape of the regurgitant orifice is not a

TR QUANTIFICATION: REGURGITANT VOLUME



- Similar ERO areas induce less RVol in TR than in MR because of the decreased driving force in TR
- The consequences with regards to venous flow reversal was the same

Tribouilloy CM, J. Am. Soc. Echocardiogr. 2002

TR QUANTIFICATION: REGURGITANT VOLUME

Table 2 Diagnostic value for severe regurgitation of various thresholds of ERO area and RVol*

	Mitral regurgitation				Tricuspid regurgitation			
Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
ERO area								
≥20 mm^2	96	37	35	96	97	36	45	96
≥30 mm^2	92	61	46	96	97	70	65	98
≥40 mm^2	88	76	56	95	94	89	82	96
RVol								
≥30 mL	100	27	33	100	94	67	62	95
≥45 mL	92	47	38	94	74	95	89	87
≥60 mL	88	67	49	94	41	100	100	75

ERO, Effective regurgitant orifice; *RVol*, regurgitant volume; *PPV*, positive predictive value; *NPV*, negative predictive value.
*Thresholds written in boldface are those with the highest sum of sensitivity and specificity.

Tribouilloy et. al. Journal of the American Society of Echocardiography Volume 15 Number 9

TR QUANTIFICATION: REGURGITANT VOLUME

Parameters	Mild	Moderate	Severe
Structural			
TV morphology	**Normal or mildly abnormal leaflets**	Moderately abnormal leaflets	**Severe valve lesions** (e.g., flail leaflet, severe retraction, large perforation)
RV and RA size	Usually normal	Normal or mild dilatation	Usually dilated*
Inferior vena cava diameter	Normal < 2 cm	Normal or mildly dilated 2.1- 2.5 cm	Dilated > 2.5 cm
Qualitative Doppler			
Color flow jet area[†]	**Small, narrow, central**	Moderate central	**Large central jet** or eccentric wall-impinging jet of variable size
Flow convergence zone	**Not visible, transient or small**	Intermediate in size and duration	**Large throughout systole**
CWD jet	**Faint/partial**/parabolic	Dense, parabolic or triangular	Dense, often triangular
Semiquantitative			
Color flow jet area (cm^2)[†]	Not defined	Not defined	**>10**
VCW (cm)[†]	<0.3	0.3-0.69	**≥0.7**
PISA radius (cm)[‡]	≤0.5	0.6-0.9	**>0.9**
Hepatic vein flow[§]	Systolic dominance	Systolic blunting	**Systolic flow reversal**
Tricuspid inflow[§]	**A-wave dominant**	Variable	E-wave >1.0 m/sec
Quantitative			
EROA (cm^2)	<0.20	0.20-0.39[‖]	≥**0.40**
RVol (2D PISA) (mL)	<30	30-44[‖]	≥45

Zoghbi W. et. al. JASE 2017

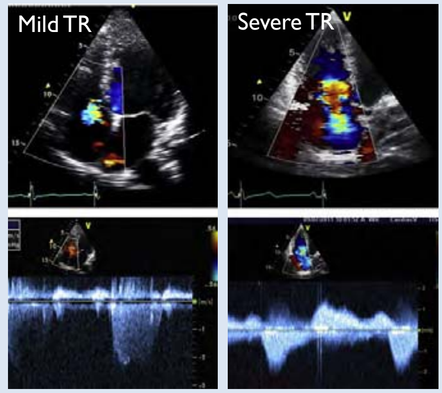
TR QUANTIFICATION: CONTINUOUS WAVE DOPPLER

Pro

- Simple
- Density is proportional to the number of RBCs reflecting the signal

Con

- Overlap between moderate and severe
- Pattern seen in severe TR may be present in patients with severely elevated RA pressure



- Faint
- Partial
- Parabolic

- Dense
- Triangular jet
- Early peaking (↑RA pressure)

Zoghbi W. et. al. JASE 2017

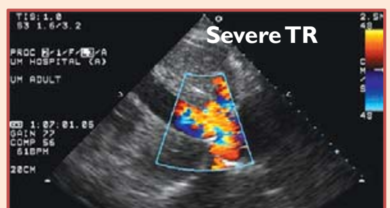
TR QUANTIFICATION: HEPATIC VEIN PULSE WAVE DOPPLER

Pro

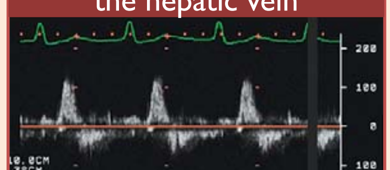
- Simple
- Can be obtained with both TTE and TEE

Con

- Depends on compliance of the RA and RV
- Affected by respiration, preload, pacemaker rhythm, CHB and atrial fibrillation/flutter



Align insonation beam with the hepatic vein



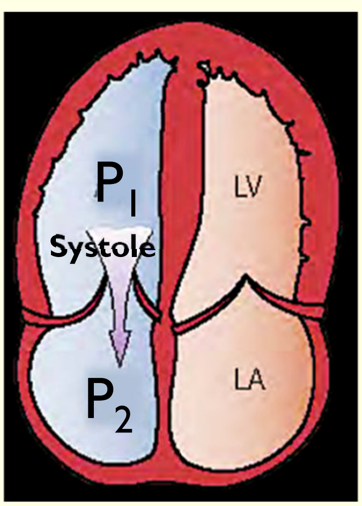
Reversal of flow in the hepatic vein with severe TR

Feigenbaum's Echocardiography and Zoghbi W. et. al. JASE 2017

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

Systolic PA pressure + IVC

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

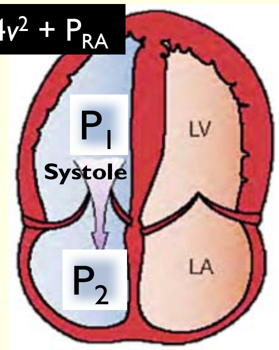


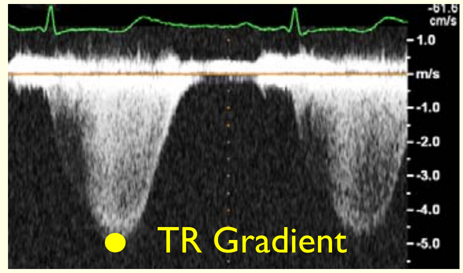
$P_1 - P_2 = 4v^2$
$P_1 = 4v^2 \times P_2$
$RVSP = 4v^2 + P_{RA}$
V = Peak velocity of TR jet
P_{RA} = Jugular venous pulse (estimated using IVC collapsibility)

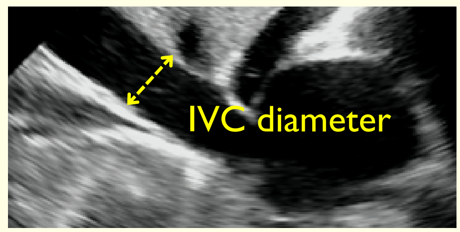
Feigenbaum's Echocardiography 7th Edition

ECHOCARDIOGRAPHIC ASSESSMENT OF THE TV

$RVSP = 4v^2 + P_{RA}$







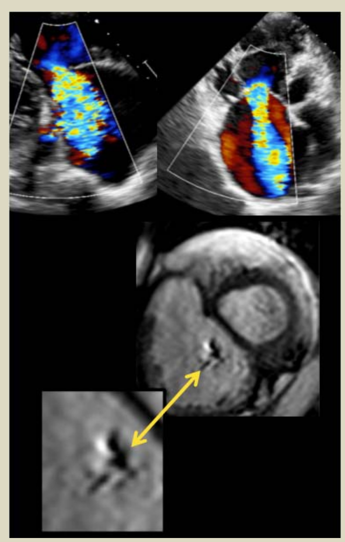
IVC Diameter	Collapse	RAP
< 2.1 cm	>50%	3 mmHg
>2.1 cm	<50%	15 mmHg
IVC does not conform		8 mmHg

Feigenbaum's Echocardiography 7th Edition

CMR IMAGING OF THE TRICUSPID VALVE: WHEN AND HOW?

Approach	TR
Preferred method for quantitation[*]	(RV SV)−(PA total forward SV)
Secondary methods for quantitation[†]	• (RV SV)−(AO total forward SV) • (RV SV)−(LV SV)
Corroborating signs of significant regurgitation	RV dilation, right atrium dilation

The strength of CMR is its ability to quantitatively assess RVol, fraction, and ventricular and atrial remodeling.



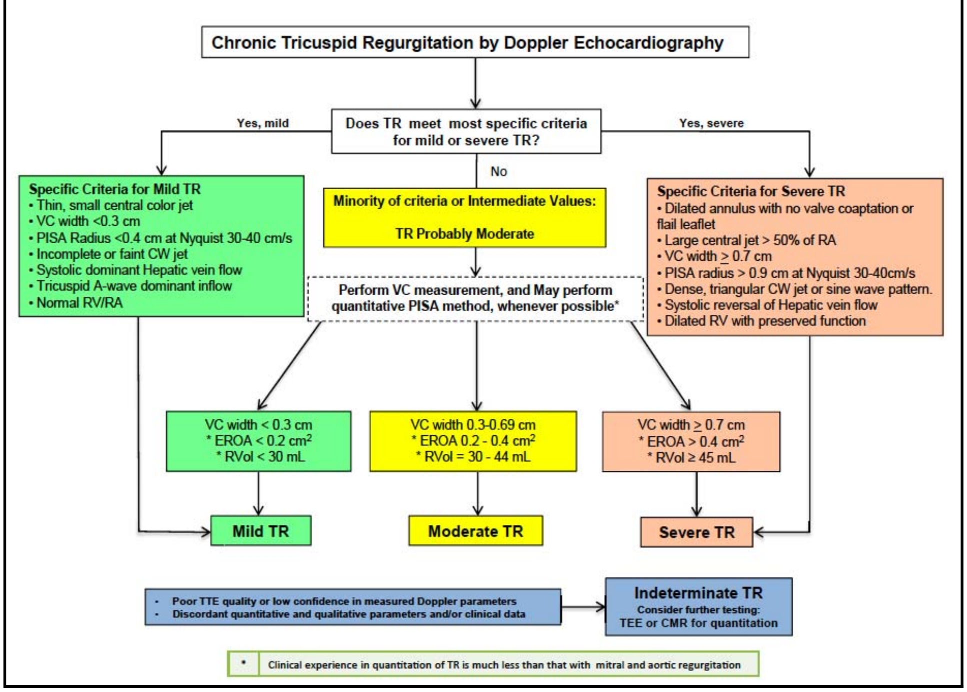
Zoghbi W. et. al. JASE 2017

GRADING OF TRICUSPID REGURGITATION SEVERITY

Parameters	Mild	Moderate	Severe
Structural			
TV morphology	**Normal or mildly abnormal leaflets**	Moderately abnormal leaflets	**Severe valve lesions** (e.g., flail leaflet, severe retraction, large perforation)
RV and RA size	Usually normal	Normal or mild dilatation	Usually dilated[*]
Inferior vena cava diameter	Normal < 2 cm	Normal or mildly dilated 2.1 - 2.5 cm	Dilated > 2.5 cm
Qualitative Doppler			
Color flow jet area[†]	**Small, narrow, central**	Moderate central	**Large central jet** or eccentric wall-impinging jet of variable size
Flow convergence zone	**Not visible, transient or small**	Intermediate in size and duration	**Large throughout systole**
CWD jet	**Faint/partial/parabolic**	Dense, parabolic or triangular	Dense, often triangular
Semiquantitative			
Color flow jet area (cm^2)[†]	Not defined	Not defined	**>10**
VCW (cm)[†]	<0.3	0.3-0.69	**≥0.7**
PISA radius (cm)[‡]	≤0.5	0.6-0.9	**>0.9**
Hepatic vein flow[§]	Systolic dominance	Systolic blunting	**Systolic flow reversal**
Tricuspid inflow[§]	**A-wave dominant**	Variable	E-wave >1.0 m/sec
Quantitative			
EROA (cm^2)	<0.20	0.20-0.39[‖]	**≥0.40**
RVol (2D PISA) (mL)	<30	30-44[‖]	≥45

JASE 2017

Zoghbi W. et. al. JASE 2017



NEW DIRECTIONS: EVALUATION OF FTR A MORE COMPREHENSIVE APPROACH

TABLE 1 Stages of Functional Tricuspid Regurgitation

	Stage 1	Stage 2	Stage 3
TR severity	None or mild	Mild or moderate	Severe
Annular diameter, mm	<40	>40	>40
Leaflet coaptation mode	Normal*	Edge-to-edge*	Absent†

*No leaflet tethering (<8 mm). †Leaflet tethering may be present (≥8 mm). ‡If leaflet tethering is present.
TR = tricuspid regurgitation.

Dreyfus, GD. et. al. J Am Coll Cardiol 2015

MECHANISMS OF TRICUSPID STENOSIS

Rheumatic

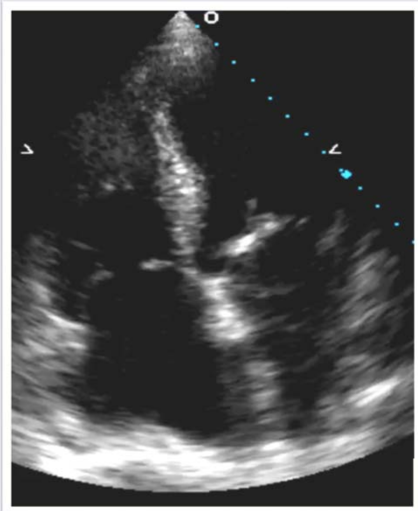
Infiltration
Carcinoid

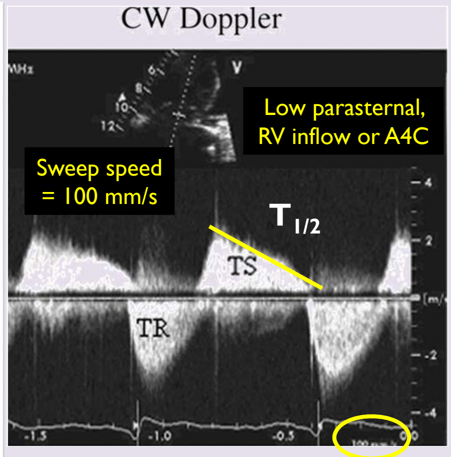
Rare
Congenital, valvular or pacemaker IE, mechanical obstruction, Lupus valvulitis

Consequence of TS

Tricuspid stenosis → Elevation of RA pressure → Right-sided heart failure

TRICUSPID STENOSIS

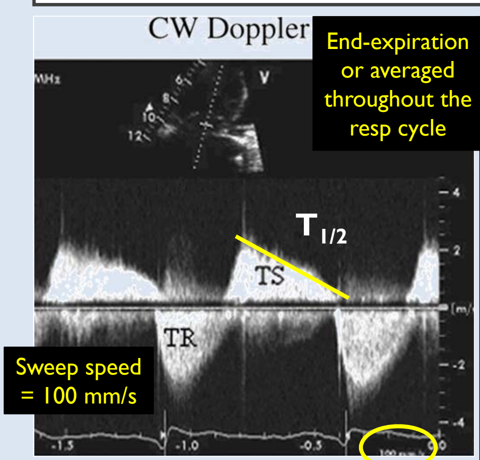




TVI = 60 cm; mean grad = 9 mmHg
$P1/2t$ = 173 ms

Zoghbi W. et. al. JASE 2017

TRICUSPID STENOSIS



TVI = 60 cm; mean grad = 9 mmHg
$P1/2t$ = 173 ms

- Hallmark of stenotic valve: ↑ transvalvular CWD velocity
- Peak inflow (normal TV) < 0.7 m/s
- TV inflow ↑ with inspiration
- In TS peak velocities >1.0 m/s up to 2 m/s with inspiration

Mean gradient = $4v^2$

TVA=190/$T_{1/2}$= 190/173= 1.1 cm^2

Zoghbi W. et. al. JASE 2017

TRICUSPID STENOSIS

Findings indicative of hemodynamically significant TS*

Specific findings	
Mean pressure gradient	$\geq$5 mmHg
Inflow time–velocity integral	$>$60 cm
$T_{1/2}$	$\geq$190 ms
Valve area by continuity equation[a]	$\leq$1 cm^{2a}
Supportive findings	
Enlarged right atrium $\geq$moderate	
Dilated inferior vena cava	

[a]Stroke volume derived from left or right ventricular outflow. In the presence of more than mild TR, the derived valve area will be underestimated. Nevertheless, a value $\leq$1 cm^2 implies a significant haemodynamic burden imposed by the combined lesion.

*with or without regurgitation

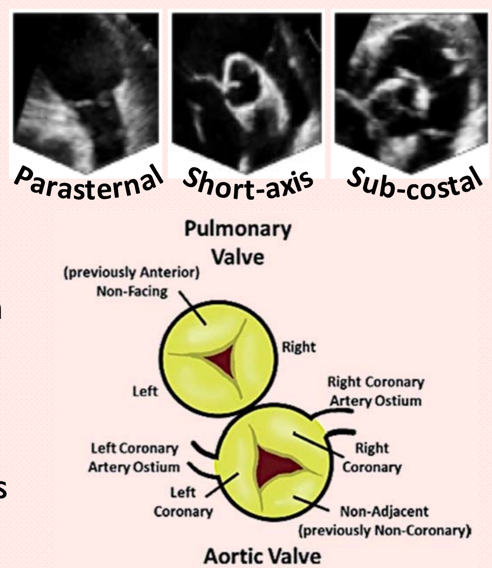
Zoghbi W. et. al. JASE 2017

THE NORMAL PULMONIC VALVE

The PV is a semilunar valve with 3 cusps

Aims of imaging

1. Inspection of valve and leaflets
2. Quantify stenosis/regurgitation
3. Assess the RVOT
4. Pulmonary annulus
5. Main PA
6. Proximal PA branches
7. RV size and function



MECHANISMS OF PULMONARY REGURGITATION

Primary
(or "Organic")

Secondary
(or "Functional")

Elevated PA pressure (volume of regurgitation usually small)

Zoghbi W. et. al. JASE 2017

PRIMARY "ORGANIC" PR

Intrinsic abnormality of PV leaflets and/or support apparatus

Acquired

- Rare (<1% of patients)
- Associated with rheumatic heart disease, endocarditis, carcinoid valve disease, pergolide-induced disease
- Rare: blunt chest trauma

Congenital heart disease

Status post balloon valvuloplasty for PS

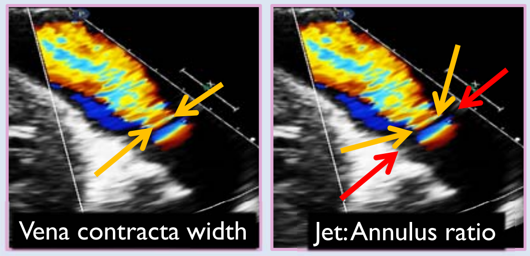
PR QUANTIFICATION: VENA CONTRACTA AND JET WIDTH: PV ANNULUS RATIO

Pro

- VC is a surrogate for ERO, is independent of flow rate and driving pressure for a fixed orifice
- Less dependent on technical factors

Con

- Problematic in multiple jets
- No cut-offs



1. Vena contracta width
2. Jet : PV annulus ratio >0.5 correlates with severe PR on CMR
3. Jet length (<10 mm = mild PR)
4. Jet area

Use: Parasternal SAX or subcostal views, zoomed in diastole

Zoghbi W. et. al. JASE 2017

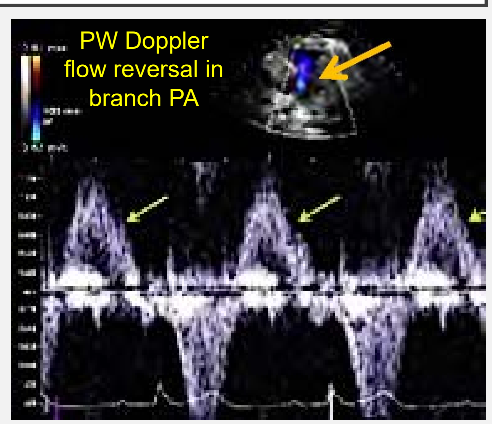
PR QUANTIFICATION: PULSE WAVE DOPPLER

Pro

- Simple supportive sign of severe PR

Con

- Depends on compliance of the PA
- Brief velocity reversal is normal



Align ultrasound beam with the flow in the RPA and LPA. Obtain PWD from both branch PAs

Zoghbi W. et. al. JASE 2017

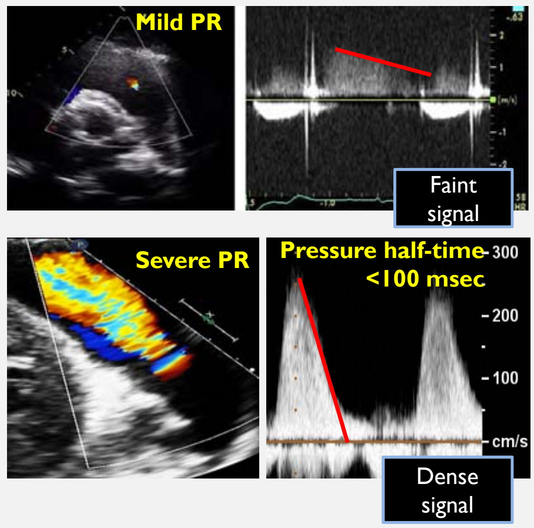
PR QUANTIFICATION: CONTINUOUS WAVE DOPPLER

Pro

- Simple
- Density is proportional to the number of red blood cell reflecting the signal
- Faint/incomplete jet is compatible with mild PR
- Values of PHT <100 msec are consistent with severe PR

Con

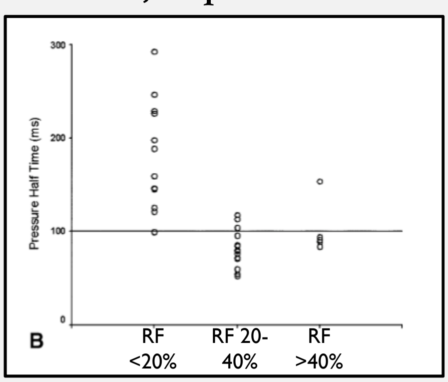
- Poor alignment of Doppler may occur in eccentric jets
- Affected by RV and PA pressure

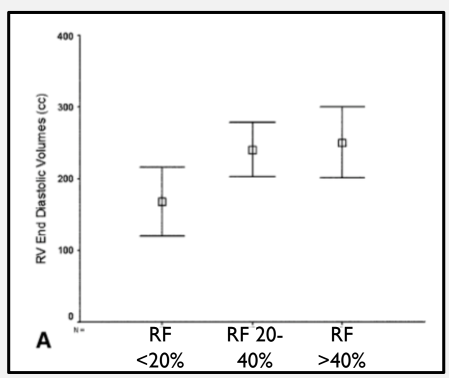


Zoghbi W. et. al. JASE 2017

PR QUANTIFICATION: CONTINUOUS WAVE DOPPLER

N=34; Repaired TOF. Echo/CMR within 3 months





RF = Regurgitant fraction measured on CMR. RV end-diastolic volumes also measured on CMR

Silversides CK et. al. J Am Soc Echocardiogr 2003;16:1057-62

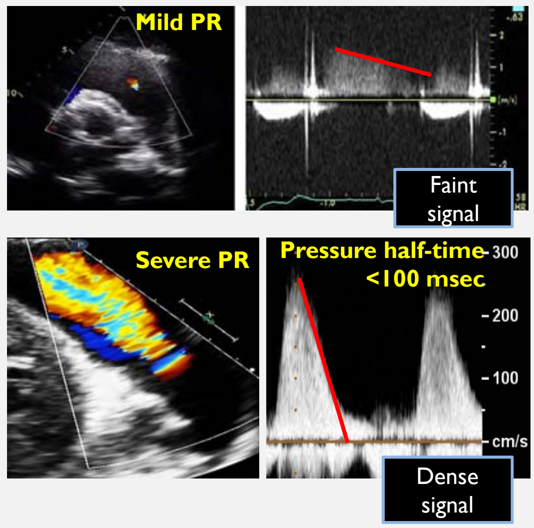
PR QUANTIFICATION: REGURGITANT VOLUME AND FRACTION

Pro

- Simple
- Density is proportional to the number of red blood cell reflecting the signal
- Faint/incomplete jet is compatible with mild PR
- Values of PHT <100 msec are consistent with severe PR

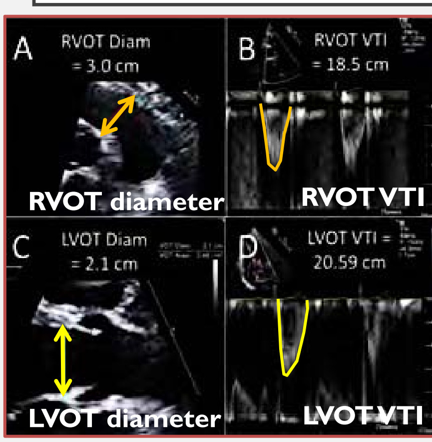
Con

- Poor alignment of Doppler may occur in eccentric jets
- Affected by RV and PA pressure



Zoghbi W. et. al. JASE 2017

PR QUANTIFICATION: REGURGITANT VOLUME AND FRACTION



$CSA_{LVOT} = \pi r_{LVOT}^2$ with r = LVOT/2

$CSA_{LVOT} = 0.785 * d^2_{LVOT}$

Zoghbi W. et. al. JASE 2017

$RVol = SV_{RVOT} - SV_{LVOT}$

$SV_{LVOT} = CSA_{LVOT} * VTI_{LVOT}$
$SV_{RVOT} = CSA_{RVOT} * VTI_{RVOT}$

$CSA_{LVOT} = 0.785 * d^2_{LVOT} * VTI_{LVOT}$
$CSA_{RVOT} = 0.785 * d^2_{RVOT} * VTI_{RVOT}$

RVoL = (0.785 $*3^2*$18.5) – 0.785 $*2.1^2*$20.59

RVol = 131 – 71
RVol = 60 mL

$RF = RVol/SV_{RVOT}$
RF = 60/131 = 46%

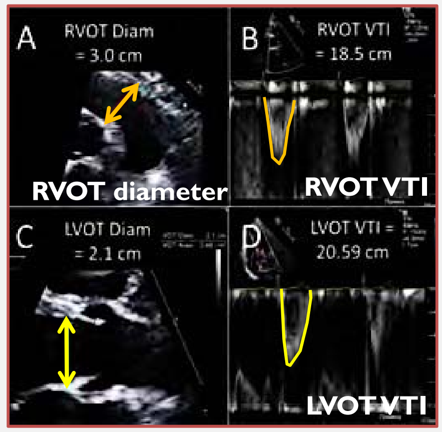
PR QUANTIFICATION: REGURGITANT VOLUME AND FRACTION

Pro

- Valid with multiple jets
- Quantitative

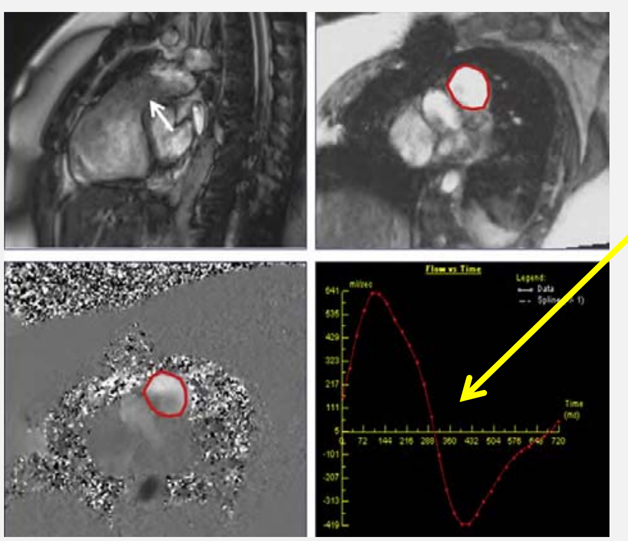
Con

- RVOT probably most difficult site to measure SV
- In case of AR would need to use mitral annulus site
- Scant experience



Zoghbi W. et. al. JASE 2017

PR QUANTIFICATION: REGURGITANT VOLUME AND FRACTION BY CMR



Forward SV by phase contrast was 129 mL, and reverse (regurgitant) volume was 78 mL, yielding an RF of 60%

Zoghbi W. et. al. JASE 2017

PR QUANTIFICATION: SUMMARY

Table 16 Echocardiographic and Doppler parameters useful in grading PR severity

Parameter	Mild	Moderate	Severe
Pulmonic valve	Normal	Normal or abnormal	Abnormal and may not be visible
RV size	Normal[*]	Normal or dilated	Dilated[†]
Jet size, color Doppler[‡]	Thin (usually <10 mm in length) with a narrow origin	Intermediate	Broad origin; variable depth of penetration
Ratio of PR jet width/pulmonary annulus			>0.7[§]
Jet density and contour (CW)	Soft	Dense	Dense; early termination of diastolic flow
Deceleration time of the PR spectral Doppler signal			Short, <260 msec
Pressure half-time of PR jet			<100 msec[‖]
PR index[¶]		<0.77	<0.77
Diastolic flow reversal in the main or branch PAs (PW)			Prominent
Pulmonic systolic flow (VTI) compared to systemic flow (LVOT VTI) by PW[#]	Slightly increased	Intermediate	Greatly increased
RF[**]	<20%	20%-40%	>40%

Zoghbi W. et. al. JASE 2017

MECHANISMS OF PULMONARY STENOSIS

Congenital

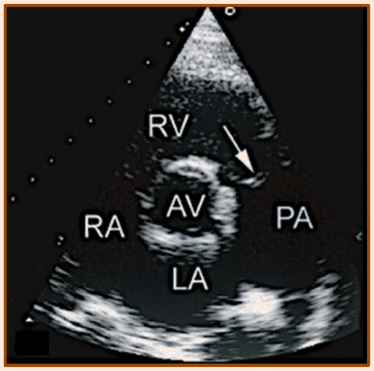
The valve can be tri-leaflet, bicuspid, unicuspid, dysplastic
Associated with TOF, DORV, complete AV canal defect
Peripheral PS may co-exist with PS (Noonanss, Williams)

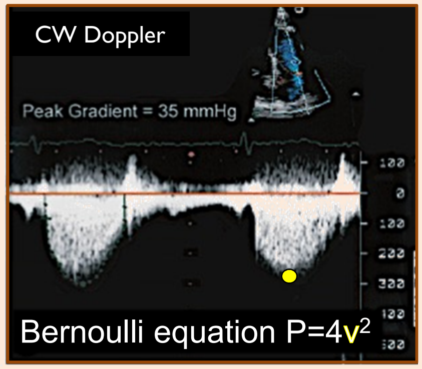
Most common

Acquired

Rheumatic, Carcinoid (combined stenosis and regurgitation)
Functional pulmonary stenosis (external compression of RVOT)
Proximal (RVOT) stenosis
Supra-valvular stenosis

PS QUANTIFICATION

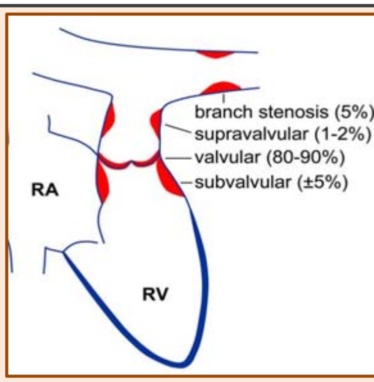


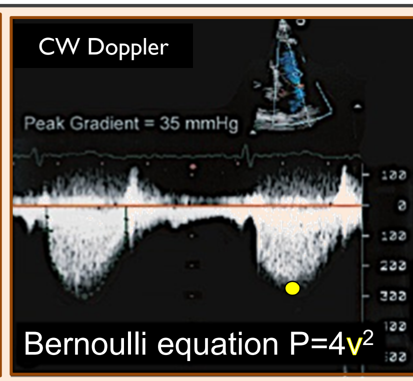


	Mild	Moderate	Severe
Peak velocity (m/s)	<3	3–4	>4
Peak gradient (mmHg)	<36	36–64	>64

Feigenbaum's Echocardiography and Hung J. et. al. JASE 2009

PS QUANTIFICATION



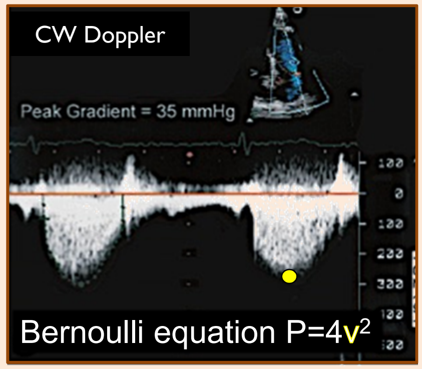


	Mild	Moderate	Severe
Peak velocity (m/s)	<3	3–4	>4
Peak gradient (mmHg)	<36	36–64	>64

Cuypers JAAE, *et al Heart* 2013
Feigenbaum's Echocardiography and Hung J. et. al. JASE 2009

PS QUANTIFICATION

sPAP =
RVSP – PV
pressure gradient



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Cuypers JAAE, *et al Heart* 2013
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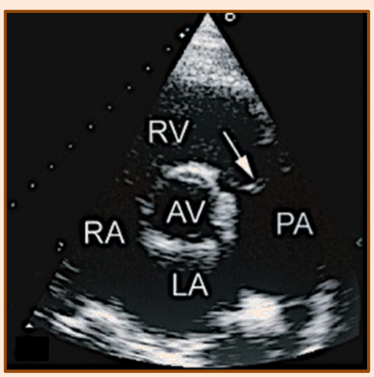

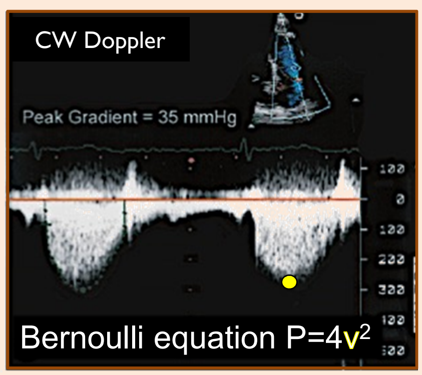

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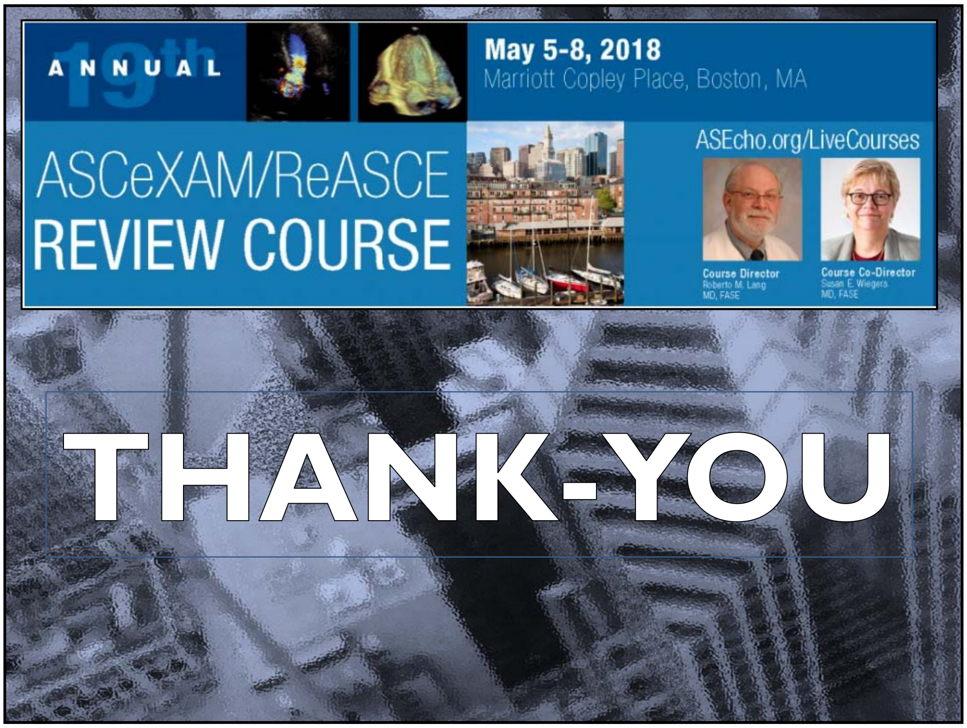
Feigenbaum's Echocardiography and Hung J. et. al. JASE 2009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